User Manual

CulvertCalc™ IA

LRFD Software for Box Culverts

Automated RCB culvert analysis and design in accordance with the AASHTO LRFD Bridge Design Specifications, 5th Edition

Developed For:

Iowa Department of Transportation

Developed By:

Foth

Foth Infrastructure & Environment, LLC

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1 Definitions

Slab – The top horizontal member of the culvert

Floor – The bottom horizontal member of the culvert

Integral Wearing Surface – The sacrificial thickness on the top surface of the slab (intended for situations where the top surface of the slab serves as the roadway surface)

Mud Mat – The sacrificial thickness on the bottom surface of the floor

2 Abbreviations

AASHTO - American Association of State Highway and Transportation Officials

Iowa DOT – Iowa Department of Transportation

LRFD – Load and Resistance Factor Design

MCFT – Modified Compression Field Theory

RCB – Reinforced Concrete Box

3 Introduction

CulvertCalc was developed for the Iowa DOT to automate the analysis and design of RCB culverts. The Microsoft Windows-based program was written to conform to the AASHTO LRFD Bridge Design Specifications, 5th Edition, with Interims through 2010, and Iowa DOT policies. Intended users for the program are professional engineers and technicians with a working knowledge of the LRFD Specifications and RCB culvert design.

CulvertCalc will analyze and design single, twin and triple barrel RCB culverts with user-specified cell span and height dimensions. Various input screens allow the user to select and/or adjust a variety of variables used in the analysis and design of a culvert such as live load properties, fill properties, load factors and material properties. By default, these variables are set to conform to the Iowa DOT policies used to design the RCB Culvert Standards. These default settings allow the user to analyze and design a standard culvert with a minimal amount of input. A customizable truck library allows the user to create custom trucks and save the library for future use.

CulvertCalc will automatically design a RCB culvert and provide a tabular output of the required member thicknesses and various reinforcing properties as well as short- and long-format design reports. CulvertCalc will also check a design for compliance to applicable code provisions using member thicknesses and reinforcing properties entered by the user and provide an on-screen summary of non-compliant components, as well as short- and long-format reports that can be printed or saved for documentation purposes.

4 Main Project Window

The Main Project Window, as shown in Figure 4-1, serves as a container for the various Input Screens and Analysis and Results Screen and also features common program functions such as opening and saving files. The commands provided in the Main Project Window are as follows:

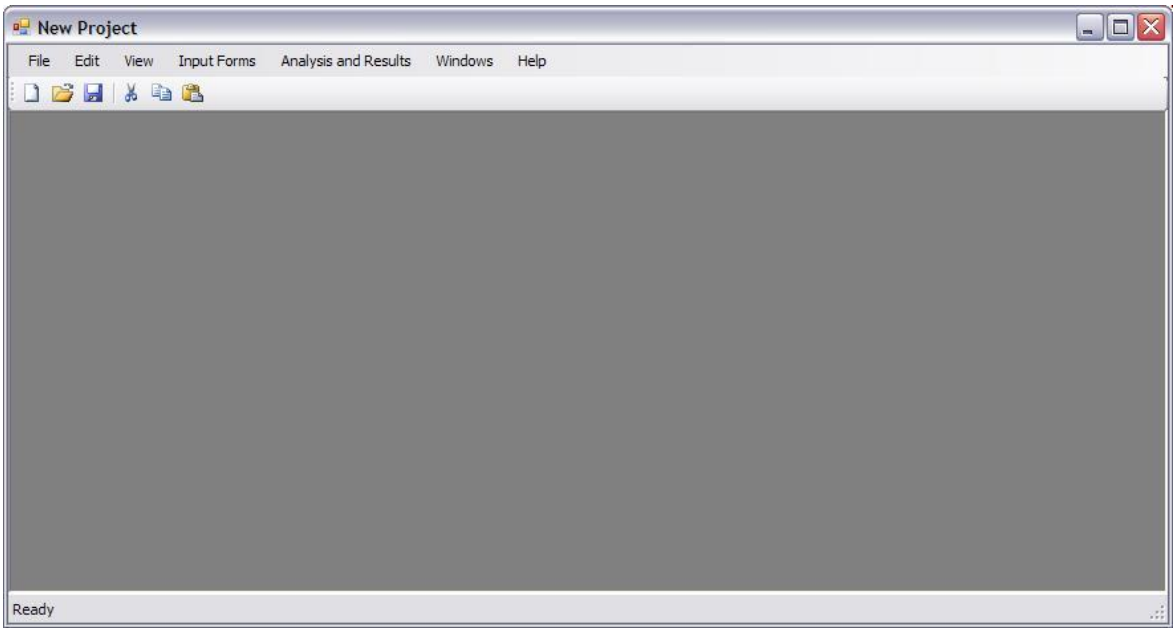

Figure 4-1 Main Project Window

- *File* | *New* menu item

  This command creates a new file with blank input fields and all input options in their default settings. A prompt will ask if the current file should be saved prior to creating the new file.

- *File* | *Open* menu item

  This command opens a standard dialog window for opening previously saved files. The files will have an ".rcb" extension. A prompt will ask if the current file should be saved prior to opening the new file.

- *File* | *Save* menu item

  This command saves the existing input information to the current file. If the file was not previously saved, a standard dialog window will open for entering the desired file name and choosing a directory location.

- *File* | *Save As* menu item

  This command saves the existing input information to a different file name. Use the standard dialog window to enter or select the desired file name and choose a directory location.

- *File* | *Preferences* menu item

  Use this command to change the directory in which the report text files will be saved. Press the button to the right of the text field to navigate to the desired directory or type the directory path directly into the text field.

- *File* | *Exit* menu item

  This command closes the CulvertCalc program. A prompt will ask if the current file should be saved prior to closing the program.

- *File* | **.rcb* menu item

  A list of most recently used files is provided under the File menu. Selecting a file name from the list will open the selected file.

- *Edit* | *Cut* menu item

  This command will delete the selected text and place the selected text on the clipboard. The shortcut keys "*Ctrl-X"* will also execute this command.

- *Edit* | *Copy* menu item

  This command places a copy of the selected text on the clipboard. The shortcut keys "*Ctrl-C"* will also execute this command.

- *Edit* | *Paste* menu item

  This command inserts text from the clipboard at the selected location. The shortcut keys "*Ctrl-V"* will also execute this command.

- *Edit* | *Select All* menu item

  This command selects all information in the current input field. The shortcut keys "*Ctrl-A"* will also execute this command.

- *View* | *Toolbar* menu item

  This command toggles the display of the toolbar on and off. The toolbar is located under the menu items and contains buttons for frequently used commands.

- *View* | *Status Bar* menu item

  This command toggles the display of the status bar on and off. The status bar is located at the bottom of the Main Project Window and displays the current program status.

- *Input Forms* | *Project Information* menu item

  This command opens the Project Information screen. If currently open, this command will bring the Project Information screen to the front of any other open screens.

- *Input Forms* | *Culvert Geometry* menu item

  This command opens the Culvert Geometry screen. If currently open, this command will bring the Culvert Geometry screen to the front of any other open screens.

- *Input Forms* | *Fill Properties* menu item

  This command opens the Fill Properties screen. If currently open, this command will bring the Fill Properties screen to the front of any other open screens.

- *Input Forms* | *Live Load* menu item

  This command opens the Live Load screen. If currently open, this command will bring the Live Load screen to the front of any other open screens.

- *Input Forms* | *Materials* menu item

  This command opens the Materials screen. If currently open, this command will bring the Materials screen to the front of any other open screens.

- *Input Forms* | *Concrete Cover Dimensions* menu item

  This command opens the Concrete Cover Dimensions screen. If currently open, this command will bring the Concrete Cover Dimensions screen to the front of any other open screens.

- *Input Forms* | *Load Factors, Load Modifiers and Exposure Factors* menu item

  This command opens Load Factors, Load Modifiers and Exposure Factors screen. If currently open, this command will bring the Load Factors, Load Modifiers and Exposure Factors screen to the front of any other open screens.

- *Analysis and Results* menu item

  This command opens Analysis and Results screen. If currently open, this command will bring the Analysis and Results screen to the front of any other open screens.

- *Windows* | *Cascade* menu item

  This command arranges all open screens in a cascade pattern starting in the upper left corner of the Main Project Window.

- *Windows* | *Tile Vertical* menu item

  This command arranges all open screens in a vertical pattern within the Main Project Window.

- *Windows* | *Tile Horizontal* menu item

  This command arranges all open screens in a horizontal pattern within the Main Project Window.

- *Windows* | *Close All* menu item

  This command closes all open screens.

- *Windows* | *Arrange Icons* menu item

  This command arranges icons for minimized windows along the bottom of the Main Project Window.

- *Help* | *Contents* menu item

  This command provides access to the User Manual and Technical Manual.

- *Help* | *About* menu item

  This command opens a screen displaying general information pertaining to CulvertCalc and the legal disclaimer.

5 Project Information

The Project Information screen is presented in Figure 5-1. The following general project information is entered in the Project Information screen:

- Project Number
- County Name
- Design Number
- Route Number
- Feature Crossed
- Designed By
- Comments

Each input field is limited to 32,767 characters. Multiline text can be entered into the *Comments* field whereas the remaining fields are limited to single line text.

Figure 5-1 Project Information Screen

6 Culvert Geometry

The Culvert Geometry screen is presented in Figure 6-1. The following geometrical dimensions for the RCB culvert are entered in the Culvert Geometry screen:

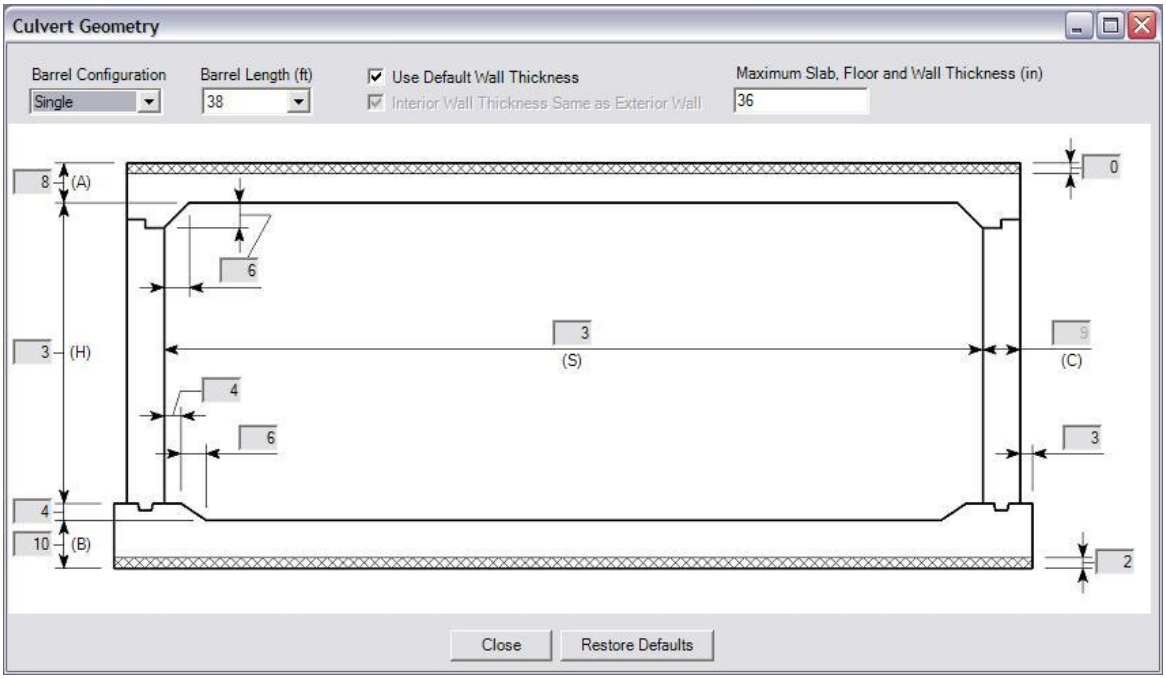

Figure 6-1 Culvert Geometry Screen

- *Barrel Configuration* combo box

  Select “Single”, “Twin” or “Triple” from the list. The barrel section graphic will update according to the selected configuration.

- *Barrel Length* combo box

  Select length of barrel between transverse construction joints from the list. Lengths are set in 3 ft. increments between 11 ft. and 59 ft.

- *Use Default Wall Thickness* checkbox
  When checked, the minimum exterior and interior (for twin and triple barrel configurations) wall thickness will be set to the maximum of 9 in. or the Cell Height divided by 12. If unchecked, the user should enter the desired minimum wall thicknesses in the appropriate input fields.

- *Maximum Slab, Floor and Wall Thickness input field*

  Enter the maximum limit for slab, floor and wall thickness. A notice will be provided during an Auto Design if the required member thickness exceeds the provided limit.

- *Interior Wall Thickness Same as Exterior Wall* checkbox

  When twin and triple barrel configurations are selected, the interior wall thickness can be set to match the exterior wall thickness by checking the checkbox. Otherwise, the interior wall thickness will be independent of the exterior wall thickness.

- *Cell Span and Cell Height* input fields

  Enter cell span and cell height in the appropriate input fields on the barrel section graphic. For twin and triple barrel configurations, all cell spans must be equal.

- *Minimum Slab, Floor, Exterior Wall, and Interior Wall Thickness* input fields

  Enter the minimum desired member thicknesses on the barrel section graphic. The program will increase the member thicknesses as necessary if the minimum thicknesses cannot withstand the applied loads.

- *Haunch, Frost Trough and Floor Extension* input fields

  Enter the haunch, frost trough and floor extension dimensions on the barrel section graphic. The haunch is set at a constant 45° angle thus the length and width dimensions will be the same value. The haunch and frost trough geometry will be the same for each corner for all barrels.

- *Mud Mat and Integral Wearing Surface* input fields

  Enter the mud mat thickness and integral wearing surface thickness on the barrel section graphic. For structural capacity calculations, the mud mat and wearing surface

are subtracted from the overall floor and slab thickness, respectively, to determine the effective thickness of these members.

Holding the cursor over each field will display a hint that defines the input field, appropriate input units and allowable value range. Cell span and cell height are entered in *feet* units and all remaining values are entered in *inch* units. A warning is displayed if an entered value is outside of an allowable range and the input field background changes to red. Press *OK* and change the value to be within the allowable range. The red background will change back to grey indicating the entered value is acceptable. All input fields, except the cell span and cell height, may be reset to default values by pressing *Restore Defaults*. Refer to the Appendix for a listing of the default, minimum, and maximum values for each field.

7 Fill Properties

The Fill Properties screen is presented in Figure 7-1. Fill height and other variables related to lateral loads on the RCB culvert are entered in the Fill Properties screen as follows:

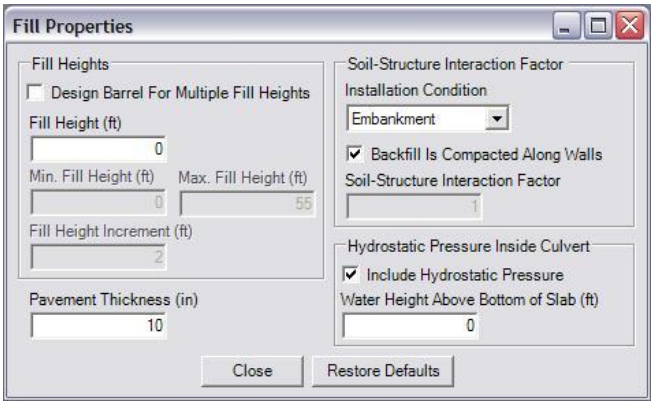

Figure 7-1 Fill Properties Screen

- *Design Barrel for Multiple Fill Heights* checkbox

  Check this box if culvert designs for multiple fill heights are desired and enter appropriate values in the *Min. Fill Height*, *Max. Fill Height*, and *Fill Height Increment* input fields. Otherwise, a single design will be provided for the fill height entered in the *Fill Height* input field.

- *Installation Condition* combo box

  Select either “Embankment” or “Trench” installation condition. If “Embankment” is selected, the soil-structure interaction factor will be internally calculated per the LRFD Specifications. The soil-structure interaction factor will be limited to 1.15 if *Backfill Is Compacted Along Walls* is checked, otherwise, the soil-structure interaction factor will be limited to 1.40. If “Trench” is selected, the *Soil-Structure Interaction Factor* input field is active and the desired soil-structure interaction factor should be entered.

- Include Hydrostatic Pressure checkbox

  Check if hydrostatic pressure due to water inside the box should be included in the design. When checked, the *Water Height Above Bottom of Slab* input field is active and the distance between the water surface and the bottom of the slab should be entered.

- *Pavement Thickness* input field

  Enter pavement thickness in this field. The pavement is treated as a surcharge load on the RCB culvert.

Holding the cursor over each input field will display a hint that defines the allowable value range. A warning is displayed if an entered value is outside of an allowable range and the input field background changes to red. Press *OK* and change the value to be within the allowable range. The red background will change back to grey indicating the entered value is acceptable. All checkboxes, combo boxes and input fields, except those in the *Fill Height* group, may be reset to default values by pressing *Restore Defaults*. Refer to the Appendix for a listing of the default, minimum, and maximum values for each field.

8 Live Load

The Live Load screen is presented in Figure 8-1. Various properties and variables related to the live load are entered on the Live Load screen as follows:

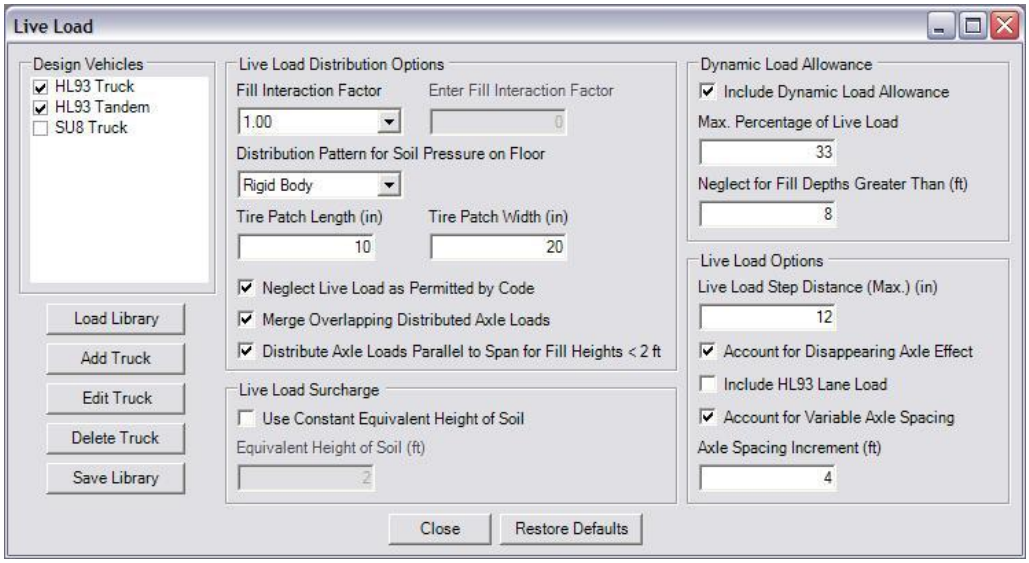

Figure 8-1 Live Load Screen

- *Design Vehicles* checked list box

  Indicate whether a vehicle will or will not be included in the design using the checkbox next to each vehicle name.

- *Load Library* button

  Press to load a previously created custom truck library to internal memory. Use the dialog box to navigate to and select the desired **.trk* file. Once opened, each truck saved in the selected file will appear in the *Design Vehicles* checked list box. If the selected file contains a truck with the same name as one that already appears in the *Design Vehicles* checked list box, a prompt will ask whether or not the existing truck should be overwritten.

- *Add Truck* button

  Press to open the *Truck Editor* screen, presented in Figure 8-2, and enter a name for the truck in the *Truck Name* input field. Select the number of axles from the *Number of Axles* combo box and enter the individual axle weights and axle spacings in the appropriate input fields. Once all information is entered, press *Save* to save the new truck to internal memory and close the program. The name of the new truck will appear in the *Design Vehicles* checked list box.

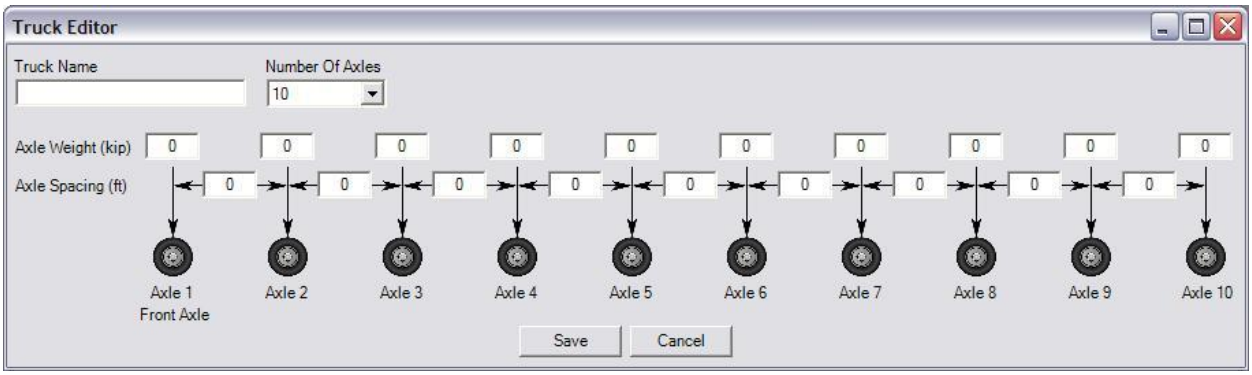

Figure 8-2 Truck Editor Screen

- *Edit Truck* button

  To edit the information associated with a particular truck, select the truck from the *Design Vehicles* checked list box and press *Edit Truck* to open the *Truck Editor*. In the *Truck Editor*, revise the appropriate values and press *Save* when finished. The revised truck is now saved to internal memory.

- *Delete Truck* button

  To delete a truck from internal memory, select the truck from the *Design Vehicles* checked list box and press *Delete Truck*. A prompt will confirm whether or not the truck should be deleted.

- *Save Library* button

  Press *Save Library* to save the trucks shown in the *Design Vehicles* checked list box (excluding the HL93 Truck, HL93 Tandem, and SU8 Truck). Use the dialog box to navigate to the desired directory and to enter the file name.

- *Fill Interaction Factor* combo box

  Select “1.00”, “1.15”, or “Other” from the *Fill Interaction Factor* combo box. If “Other” is selected, enter the desired fill interaction factor in the *Enter Fill Interaction Factor* input field.

- *Distribution Pattern for Soil* Pressure on Floor combo box

  Select “Rigid Body” if the soil pressure acting on floor due to live load should be assumed to vary lineally along the width of the floor. Otherwise, select “Uniform” to assume the soil pressure acting on the floor due to live load is uniform along the width of the floor.

- *Tire Patch Length and Tire Patch Width* input fields

  Enter the tire patch dimensions in the appropriate fields. The tire patch length is measured perpendicular to the span and the tire patch width is measured parallel to the span.

- *Neglect Live Load as Permitted by Code* checkbox

  Check if the live load should be neglected when the fill height exceeds the limits specified in the LRFD Specifications. If unchecked, live load will be included regardless of fill height.

- *Merge Overlapping Distributed Axle Loads* checkbox

  If checked, any distributed axle loads that overlap will be summed and uniformly distributed over the extent of the overlapping axles. If unchecked, the distributed axle loads will simply overlap each other.

- *Distribute Axle Loads Parallel to Span for Fill Heights < 2 ft* checkbox

  If checked, the concentrated axle loads for fill heights less than 2 ft. will be distributed parallel to the span based on the fill height, fill interaction factor, and the tire patch length. If unchecked, each axle load will be treated as a concentrated force for fill heights less than 2 ft.

- *Include Dynamic Load Allowance* checkbox

  Check if the dynamic load allowance should be added to the live load and uncheck to neglect the dynamic load allowance. If checked, the *Max. Percentage of Live Load* and

Neglect for Fill Depths Greater Than input fields will become active. Enter the percentage of live load to use when the top of the slab is also the roadway surface (0 ft. fill height) in the *Max. Percentage of Live Load* input field. Enter the fill height at which the dynamic load allowance is to be neglected in the *Neglect for Fill Depths Greater Than* input field. Dynamic load allowance will vary lineally for fill heights between 0 ft. and the value entered in the *Neglect for Fill Depths Greater Than* input field.

- *Live Load Step Distance (Max.)* input field

  Each truck is "walked" across the RCB culvert in a series of successive positions. Enter the distance between successive truck positions in the *Live Load Step Distance (Max.)* input field. A smaller distance will result in more live load positions giving a more refined section force envelope. A larger distance will result in less live load positions and shorter computational time. The default value, 12 in., is recommended as a balance between acceptable section force envelopes and reasonable computational time.

- *Account for Disappearing Axle Effect* checkbox

  The disappearing axle effect occurs when axle loads that do not contribute to maximizing the force effect are eliminated from the analysis. Check the *Account for Disappearing Axle Effect* checkbox to apply the disappearing axle effect in the analysis. Uncheck to include all axles in the analysis regardless of whether or not they maximize a particular force effect.

- *Include HL93 Lane Load* checkbox

  If checked, HL93 lane load will be included in the HL93 live load analysis. If neither the HL93 truck nor HL93 tandem is selected in the *Design Vehicles* checked list box, the HL93 live load analysis will consist solely of the HL93 lane load. HL93 lane load is neglected when the *HL93 Lane Load* checkbox is unchecked. HL93 lane load is always neglected from the SU8 and owner-defined live load analysis, regardless of whether or not the *HL93 Lane Load* checkbox is checked.

- *Account for Variable Axle Spacing* checkbox

  Variable axle spacing is only applicable to the HL93 Truck and the SU8 truck. For the HL93 truck, the rear axle spacing can vary from 14 ft. to 30 ft. For the SU8 truck, the front axle spacing can vary from 6 ft. to 14 ft. If checked, the *Axle Spacing Increment* input field will become active. For each successive run of the truck across the RCB culvert, the variable axle spacing will be increased by the value entered in the *Axle Spacing Increment* input field until either the maximum axle spacing is reached or the axle spacing is greater than the overall width of the RCB culvert. If unchecked, the shortest axle spacing will be used in the live load analysis.

- *Use Constant Equivalent Height of Soil* checkbox

  If checked, the equivalent height of soil used to account for live load surcharge will be set at the value specified in the *Equivalent Height of Soil* input field. If unchecked, the equivalent height of soil will be calculated based on fill height and the RCB culvert geometry.

Holding the cursor over each input field will display a hint that defines the allowable value range. A warning is displayed if an entered value is outside of an allowable range and the input field background changes to red. Press *OK* and change the value to be within the allowable range. The red background will change back to grey indicating the entered value is acceptable. All checkboxes, combo boxes and input fields, except those in the *Design Vehicles* checked list box, may be reset to default values by pressing *Restore Defaults*. Refer to the Appendix for a listing of the default, minimum, and maximum values for each field.

9 Materials

The Materials screen is presented in Figure 9-1. The following properties for the various materials used in the RCB culvert analysis and design are entered in the *Materials* screen:

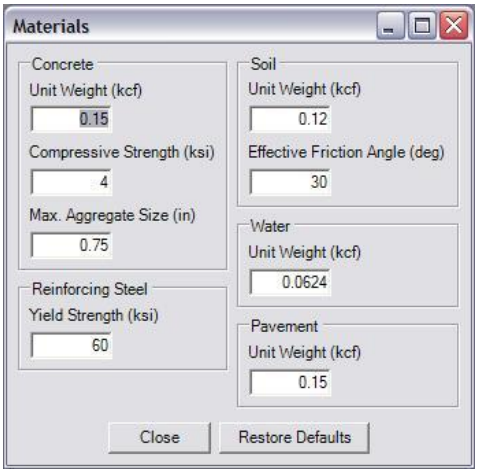

Figure 9-1 Materials Screen

- Concrete Unit Weight
- Concrete Compressive Strength
- Maximum Aggregate Size
- Reinforcing Steel Yield StrengthSoil Unit Weight
- Effective Friction Angle for Soil
- Water Unit Weight
- Pavement Unit Weight

Holding the cursor over each input field will display a hint that defines the allowable value range. A warning is displayed if an entered value is outside of an allowable range and the input field background changes to red. Press *OK* and change the value to be within the allowable range. The red background will change back to grey indicating the entered value is acceptable. All input fields may be reset to default values by pressing *Restore Defaults*. Refer to the Appendix for a listing of the default, minimum, and maximum values for each field.

10 Concrete Cover Dimensions

The Concrete Cover Dimensions screen is presented in Figure 10-1. Concrete cover dimensions for various locations in the RCB culvert are entered in the *Concrete Cover Dimensions* screen as follows:

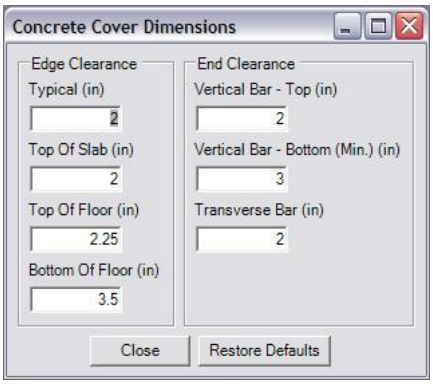

Figure 10-1 Concrete Cover Dimensions Screen

- Typical Edge Clearance
- Edge Clearance for Transverse Reinforcing in Top of Slab
- Edge Clearance for Transverse Reinforcing in Top of Floor
- Edge Clearance for Transverse Reinforcing in Bottom of Floor
- End Clearance at Top of Vertical Reinforcing
- End Clearance at Bottom of Vertical Reinforcing
- End Clearance at Ends of Transverse Reinforcing

Holding the cursor over each input field will display a hint that defines the allowable value range. A warning is displayed if an entered value is outside of an allowable range and the input field background changes to red. Press *OK* and change the value to be within the allowable range. The red background will change back to grey indicating the entered value is acceptable. All input fields may be reset to default values by pressing *Restore Defaults*. Refer to the Appendix for a listing of the default, minimum, and maximum values for each field.

11 Load Factors, Load Modifiers and Exposure Factors

The Load Factors, Load Modifiers and Exposure Factors screen is presented in Figure 11-1. Load factors and load modifiers for Strength I, Strength II and Service I load combinations and exposure factors for checking crack control provisions are entered in the *Load Factors* screen as follows:

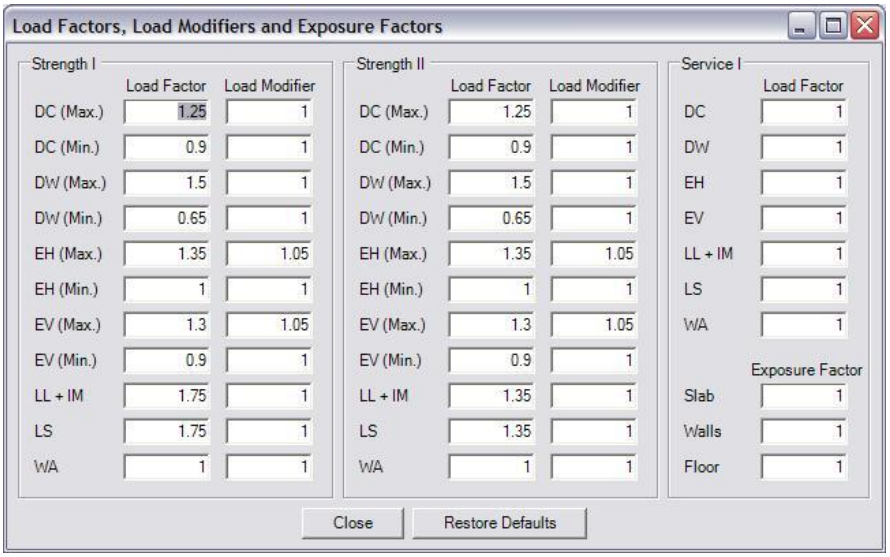

Figure 11-1 Load Factors, Load Modifiers and Exposure Factors Screen

Load factors and load modifiers for Strength I and Strength II Load Combinations-

- DC (Min. & Max.)
- DW (Min. & Max.)
- EH (Min. & Max.)
- EV (Min. & Max.)
- LL + IM
- LS
- WA

Load factors for Service I Load Combination-

- DC
- DW
- EH
- EV

- LL + IM
- LS
- WA

Exposure Factors-

- Slab
- Walls
- Floor

Holding the cursor over each input field will display a hint that defines the allowable value range. A warning is displayed if an entered value is outside of an allowable range and the input field background changes to red. Press *OK* and change the value to be within the allowable range. The red background will change back to grey indicating the entered value is acceptable. All input fields may be reset to default values by pressing *Restore Defaults*. Refer to the Appendix for a listing of the default, minimum, and maximum values for each field.

12 Analysis and Results

The Analysis and Results screen is presented in Figure 12-1. The various options in this screen for performing a RCB culvert design and viewing the results are as follows:

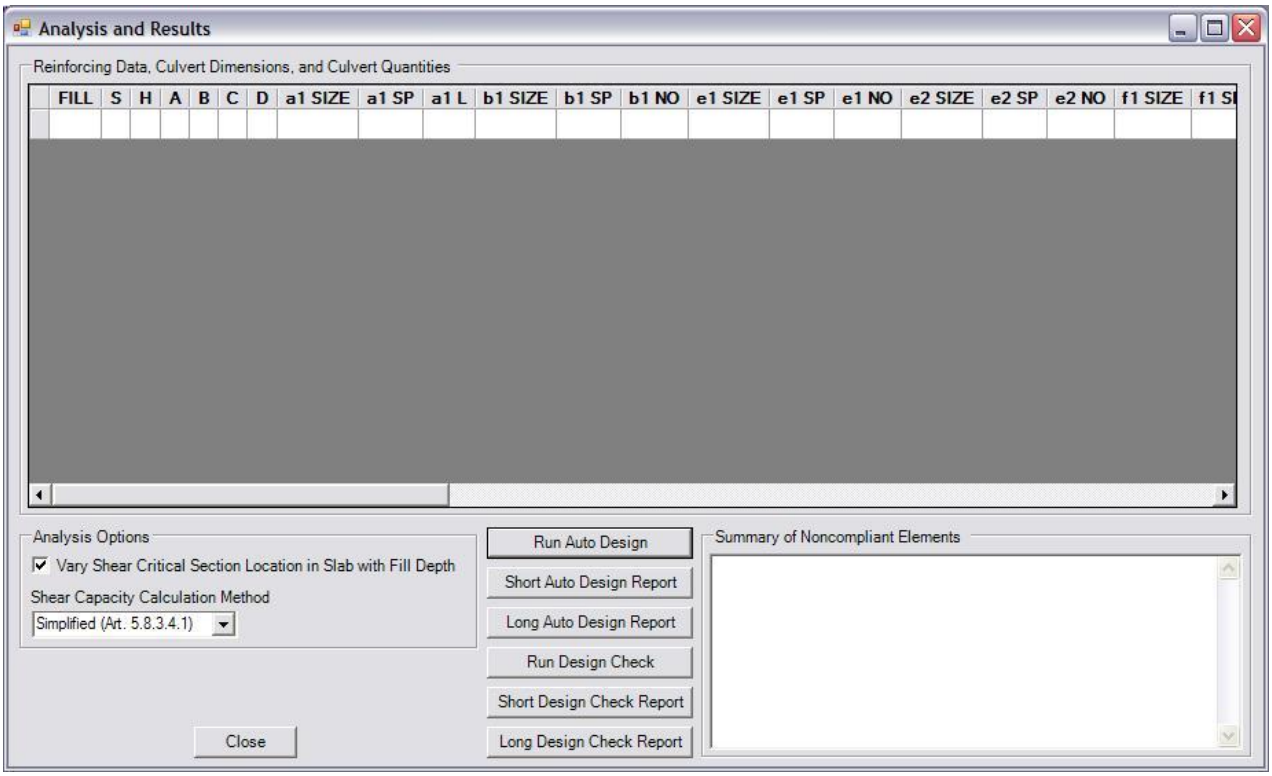

Figure 12-1 Analysis and Results Screen

- *Vary Shear Critical Section Location in Slab with Fill Depth checkbox*

  If checked, the location of the critical section in the slab used in the shear capacity calculations will depend upon the fill depth. For fill depths less than 2 ft., the critical section will be taken at the end of the haunch. For fill depths 2 ft. or greater, the critical section will be taken at a distance d_v from the end of the haunch. If not checked, the critical section location for the slab shear capacity calculations will be at a distance d_v from the end of the haunch, regardless of fill depth.

- *Shear Capacity Calculation Method* combo box

  Select “Simplified (Art. 5.8.3.4.1)”, “MCFT (Art. 5.8.3.4.2)” or “Best Result” from the list. “Best Result” will utilize the shear calculation method that returns the greatest shear capacity. For all three methods, the provisions of Art. 5.14.5.3 are utilized for determining the shear capacity of slabs and floors on RCB culverts under 2 ft. or more of fill.

- *Run Auto Design* button

  By pressing this button, CulvertCalc will automatically design the RCB culvert based on the information entered and options selected in the input forms. The status bar, if displayed, will indicate the progress of the calculations being performed by the software. Several iterations may automatically be performed to converge on a solution. Once the calculations are complete, the *Reinforcing Data, Culvert Dimensions, and Culvert Quantities* table will be populated with output from the design calculations. Column headings correlate with the Iowa DOT RCB culvert standards. If multiple fill heights were specified, multiple lines of data will be provided in the table with each line corresponding to a specific fill height.

- *Short Auto Design Report* button

  Pressing this button will open the Notepad application and display the contents of the short-format auto design report. The short-format report contains an echo of the input parameters and a summary of the RCB culvert design. Within Notepad, the report may be printed or saved for later reference. If multiple fill heights were specified, one report will be generated for each fill height. To view a report for a particular fill height, select any cell within the row of output data for that particular fill height and press *Short Auto Design Report*.

- *Long Auto Design Report* button

  Pressing this button will open the Notepad application and display the contents of the long-format auto design report. The long-format report contains an echo of the input parameters, structural model properties, section forces for the component loads and load combinations, details of the concrete design calculations and a summary of the RCB culvert design. Structural model properties, section forces for the component loads and load combinations, and details of the concrete design calculations will be presented

multiple times when more than one iteration is necessary to converge on a solution. Within Notepad, the report may be printed or saved for later reference. If multiple fill heights were specified, one report will be generated for each fill height. To view a report for a particular fill height, select any cell within the row of output data for that particular fill height and press *Long Auto Design Report*.

- *Run Design Check* button

  The Design Check feature allows a specified design to be evaluated for conformance to the AASHTO LRFD Bridge Design Specifications. To check a design, the barrel configuration (single, twin or triple) should first be identified in the *Culvert Geometry* screen. This will format the *Reinforcing Data, Culvert Dimensions, and Culvert Quantities* table in the Analysis and Results screen for the desired barrel configuration. The appropriate values should then be entered in the table for the design that is being evaluated. Units for fill height (FILL), cell span (S) and cell height (H) need to be entered in decimal feet units. Reinforcing bar lengths need to be entered in feet-inch format (i.e. 5'-9) and all other dimensions are entered in decimal inch units.

  Once all cells in one row are populated with the desired design information, input values and option selections on all input forms should be modified as desired for the design evaluation. The values entered in the *Reinforcing Data, Culvert Dimensions, and Culvert Quantities* table for fill height (FILL), cell span (S), cell height (H), slab thickness (A), floor thickness (B) and wall thickness (C) will overwrite values entered on the *Fill Properties* and *Culvert Geometry* input screens.

  Next, select any cell in the desired row of data in the *Reinforcing Data, Culvert Dimensions, and Culvert Quantities* table and press *Run Design Check* to evaluate the design. The status bar, if displayed, will indicate the progress of the calculations being performed by CulvertCalc. Once complete, the *Summary of Noncompliant Elements* textbox will be populated with results from the design evaluation. A message stating all requirements are satisfied will be displayed if all elements are found to conform to the LRFD Specifications. Otherwise, a list of each nonconforming element will be displayed.

- *Short Design Check Report* button

  Pressing this button will open the Notepad application and display the contents of the short-format design check report. The short-format report contains an echo of the input parameters and a summary of the various design checks performed. Required values are compared to corresponding provided values and a statement as to whether the provided reinforcing is or is not adequate is presented. Within Notepad, the report may be printed or saved for later reference.

- *Long Design Check Report* button

  Pressing this button will open the Notepad application and display the contents of the long-format design check report. The long-format report contains an echo of the input parameters, structural model properties, section forces for the component loads and

load combinations, and a summary of the various design checks performed. Required values are compared to corresponding provided values and a statement as to whether the provided reinforcing is or is not adequate is presented. Within Notepad, the report may be printed or saved for later reference.

Appendix A Input Field Default, Minimum, and Maximum Values

	Input Field	Units	Default Value	Min. Value	Max. Value
Culvert Geometry	Cell Span	ft.	3	3	20
	Cell Height	ft.	3	3	20
	Min. Slab Thickness	in.	8	8	36
	Min. Ext. Wall Thickness	in.	9	8	36
	Min. Int. Wall Thickness	in.	9	8	36
	Min. Floor Thickness	in.	10	8	40
	Max. Slab, Floor and Wall Thickness	in.	36	12	48
	Haunch Length/Width	in.	6	0	12
	Frost Trough Height	in.	4	0	12
	Width of Constant Depth Portion of Frost Trough	in.	4	0	6
	Width of Tapered Portion of Frost Trough	in.	6	0	6
	Floor Extension Beyond Outside Face of Exterior Wall	in.	3	0	9
	Integral Wearing Surface Thickness	in.	0	0	3
	Mud Mat Thickness	in.	2	0	3
Fill Properties	Fill Height	ft.	0	0	100
	Min. Fill Height	ft.	0	0	99
	Max. Fill Height	ft.	55	1	100
	Fill Height Increment	ft.	2	0.25	5
	Soil-Structure Interaction Factor	--	1	0	5
	Water Height Above Bottom of Slab	ft.	0	0	100
	Pavement Thickness	in.	10	0	24
Live Load	Enter Fill Interaction Factor	--	0	0	5
	Tire Patch Length	in.	10	0	50
	Tire Patch Width	in.	20	0	50
	Equivalent Height of Soil	ft.	2	0	10
	Max. Percentage of Live Load	%	33	0	100
	Neglect for Fill Depths Greater Than	ft.	8	0.1	100
	Live Load Step Distance (Max.)	in.	24	1	30
	Axle Spacing Increment	ft.	4	1	8
Materials	Concrete Unit Weight	kcf	0.15	0	1
	Concrete Compressive Strength	ksi	4	1	20
	Concrete Max. Aggregate Size	in.	0.75	0.25	2
	Reinforcing Steel Yield Strength	ksi	60	10	100
	Soil Unit Weight	kcf	0.12	0	1
	Effective Friction Angle	deg	30	0	89
	Water Unit Weight	kcf	0.0624	0	1
	Pavement Unit Weight	kcf	0.15	0	1

(Table continued on next page)

	Input Field	Units	Default Value	Min. Value	Max. Value
Concrete Cover Dim.	Edge Clearance - Typical	in.	2	1	4
	Edge Clearance - Top of Slab	in.	2	1	4
	Edge Clearance - Top of Floor	in.	2.25	1	4
	Edge Clearance - Bottom of Floor	in.	3.5	1	4
	End Clearance - Vertical Bar - Top	in.	2	1	4
	End Clearance - Vertical Bar - Bottom (Min.)	in.	3	1	4
	End Clearance - Transverse Bar	in.	2	1	4
Load Factors, Load Modifiers and Exposure Factors	Strength I - Load Factor - DC (Max.)	--	1.25	0	10
	Strength I - Load Factor - DC (Min.)	--	0.9	0	10
	Strength I - Load Factor - DW (Max.)	--	1.5	0	10
	Strength I - Load Factor - DW (Min.)	--	0.65	0	10
	Strength I - Load Factor - EH (Max.)	--	1.35	0	10
	Strength I - Load Factor - EH (Min.)	--	1	0	10
	Strength I - Load Factor - EV (Max.)	--	1.3	0	10
	Strength I - Load Factor - EV (Min.)	--	0.9	0	10
	Strength I - Load Factor - LL + IM	--	1.75	0	10
	Strength I - Load Factor - LS	--	1.75	0	10
	Strength I - Load Factor - WA	--	1	0	10
	Strength I - Load Modifier - DC (Max.)	--	1	0	10
	Strength I - Load Modifier - DC (Min.)	--	1	0	10
	Strength I - Load Modifier - DW (Max.)	--	1	0	10
	Strength I - Load Modifier - DW (Min.)	--	1	0	10
	Strength I - Load Modifier - EH (Max.)	--	1.05	0	10
	Strength I - Load Modifier - EH (Min.)	--	1	0	10
	Strength I - Load Modifier - EV (Max.)	--	1.05	0	10
	Strength I - Load Modifier - EV (Min.)	--	1	0	10
	Strength I - Load Modifier - LL + IM	--	1	0	10
	Strength I - Load Modifier - LS	--	1	0	10
	Strength I - Load Modifier - WA	--	1	0	10

(Table continued on next page)

	Input Field	Units	Default Value	Min. Value	Max. Value
Load Factors, Load Modifiers and Exposure Factors	Strength II - Load Factor - DC (Max.)	--	1.25	0	10
	Strength II - Load Factor - DC (Min.)	--	0.9	0	10
	Strength II - Load Factor - DW (Max.)	--	1.5	0	10
	Strength II - Load Factor - DW (Min.)	--	0.65	0	10
	Strength II - Load Factor - EH (Max.)	--	1.35	0	10
	Strength II - Load Factor - EH (Min.)	--	1	0	10
	Strength II - Load Factor - EV (Max.)	--	1.3	0	10
	Strength II - Load Factor - EV (Min.)	--	0.9	0	10
	Strength II - Load Factor - LL + IIM	--	1.35	0	10
	Strength II - Load Factor - LS	--	1.35	0	10
	Strength II - Load Factor - WA	--	1	0	10
	Strength II - Load Modifier - DC (Max.)	--	1	0	10
	Strength II - Load Modifier - DC (Min.)	--	1	0	10
	Strength II - Load Modifier - DW (Max.)	--	1	0	10
	Strength II - Load Modifier - DW (Min.)	--	1	0	10
	Strength II - Load Modifier - EH (Max.)	--	1.05	0	10
	Strength II - Load Modifier - EH (Min.)	--	1	0	10
	Strength II - Load Modifier - EV (Max.)	--	1.05	0	10
	Strength II - Load Modifier - EV (Min.)	--	1	0	10
	Strength II - Load Modifier - LL + IIM	--	1	0	10
	Strength II - Load Modifier - LS	--	1	0	10
	Strength II - Load Modifier - WA	--	1	0	10
	Service I - Load Factor - DC	--	1	0	10
	Service I - Load Factor - DW	--	1	0	10
	Service I - Load Factor - EH	--	1	0	10
	Service I - Load Factor - EV	--	1	0	10
	Service I - Load Factor - LL + IM	--	1	0	10
	Service I - Load Factor - LS	--	1	0	10
	Service I - Load Factor - WA	--	1	0	10
	Service I - Exposure Factor - Slab	--	1	0.1	1
	Service I - Exposure Factor - Walls	--	1	0.1	1
	Service I - Exposure Factor - Floor	--	1	0.1	1